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Case studies and testing of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009

Case studies and testing of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009

Case Studies – Application of UNFC-2009 to uranium resources in China and Niger

Prepared by the Task Force on Application of UNFC-2009 to Nuclear Fuel Resources

I. Introduction

1. This document focuses on the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) to uranium resources in selected deposits in China and Niger.

2. The first case study relates to the application of UNFC-2009 to the uranium resources in the Yili Basin, North West China. In the case study, issues related to In-situ Leaching (ISL) and the use of UNFC-2009 for such projects are raised. ISL, also known as solution mining, is a mining process used to recover uranium through boreholes drilled into a deposit. It involves leaving the ore where it is in the ground, and recovering the minerals from it by dissolving them and pumping the pregnant solution to the surface where the minerals can be recovered. There are similar cases in Australia, Kazakhstan and the United States of America which generate significant debate when handled only with the Committee for Mineral Reserves International Reporting Standards (CRIRSCO) Template, due to the fact that the recovery factor is usually a major uncertainty.

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3. The second case study focuses on the application of UNFC-2009 to the Azelik Uranium Deposit located in the north-western region of Niger.

4. In both case studies the uranium resources were originally classified according to the China Mineral Reserves and Resources Classification System (CMRRCS).

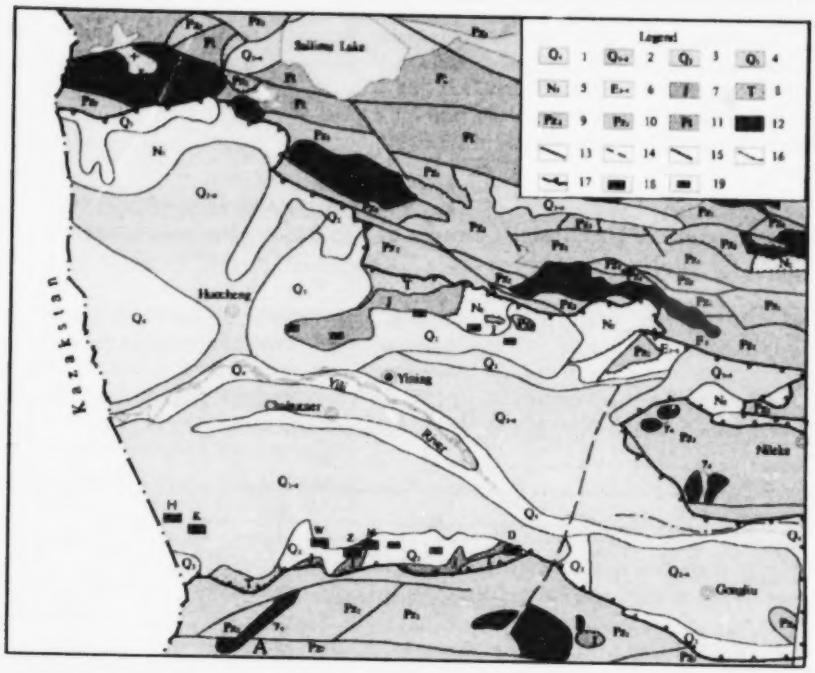
II. Application of UNFC-2009 to the Uranium Resources in the Yili Basin, China - A case study on the mapping of CMRRCS to UNFC-2009

5. This case study was prepared with the technical input of Mr. Li Shengxiang and Mr. Yu Hengxu of the China National Nuclear Corporation (CNNC), Mr. Harikrishnan Tulsidas of the International Atomic Energy Agency (IAEA) and Mr. Brad Van Gosen of the United States Geological Survey (USGS). The case study provides considerations related to the application of UNFC-2009 to estimates of uranium resources in the Yili Basin, North West China. The uranium resources of this basin were originally classified according to the China Mineral Reserves and Resources Classification System (CMRRCS) and this case study demonstrates that the quantities can be transparently transferred to UNFC-2009.

A. Uranium Exploration and Mining in the Yili Basin

6. The Yili Basin, situated in the western part of the Tianshan Tectonic Belt, North West China, is a Meso-Cenozoic intermountain basin developed on the basement of an old Precambrian block (Figure 1). The coordinates of the centre of the Yili Basin are E81°05, N43°50.

Figure 1.
Geological map of the Yili Basin



Legend: 1-Holocene; 2-Upper Pleistocene-Holocene; 3-Middle Pleistocene; 4-Lower Pleistocene; 5-Pliocene; 6-Eocene-Oligocene; 7-Jurassic; 8-Triassic; 9-Upper Paleozoic; 10-Lower Paleozoic; 11-Proterozoic; 12-Hercynian granite; 13-fault; 14-inferred fault; 15-buried fault; 16-unconformity; 17-boundary of the basin; 18-U Deposit; 19-U occurrence; K-Kujiertai deposit; W-Wukuerqi Deposit; Z-Zhajistan Deposit; M-Mengqiguer Deposit; D-Daladi Deposit; H-Honghaigou Deposit.

7. The uranium mineralization is mainly hosted in the coal-bearing clastic rocks of the Shuixigou Group ($J_{1-2}sh$), the Lower-Middle Jurassic (Figure 1). The ore-hosting Shuixigou Group ($J_{1-2}sh$) can be further divided into three formations, namely, Badaowan Formation (J_1b), Sangonghe Formation (J_1s) and Xishanyao Formation (J_2x)[1,2].

8. Uranium prospecting work began in this region in the early 1950s. During the 1950s and 1960s, the prospecting focused on coal-type uranium resources; two coal-type deposits – the Daladi Deposit and the Mengqiguer Deposit – were discovered during that time. After being suspended for about 20 years, the prospecting work restarted in the early 1990s and focused on in-situ leach (ISL) amenable sandstone-type uranium deposits in the southern margin of Yili Basin. Following 25 years of geological exploration efforts, five in-situ

[1] Li Shengxiang et al., Geologic Evolution and Uranium Metallogenic Regularity of the Yili Basin, Sandstone-type Uranium Deposits in China: Geology and Exploration Techniques, Atomic Energy Press, 2002, 9: p. 53-64.

[2] Lin Shuangxin, Wang Baoqun, Li Shengxiang. 2004. Characteristics of uranium mineralization and ore-controls of Kujieertai Deposit, Yili Basin, Xinjiang Autonomous Region. IAEA-TECDOC-1396. p. 79-90.

leachable sandstone-type uranium deposits – the Mengqiguer, Zhajistan, Wukuerqi, Kujiertai and Honghaigou Deposits – have been delineated, with the total uranium resources amenable to ISL extraction estimated at over 30,000 tU (metric tons of uranium).

9. Uranium production and trial production activities using the ISL method are currently ongoing in the Mengqiguer, Zhajistan, Wukuerqi and Kujiertai Deposits, forming the largest uranium production centre in China. The total production capacity of the four deposits is around 400 tU per annum, and will expand to 500 tU per annum in the near future. Exploration work continues in the existing deposit extensions and their adjoining areas.

B. Classification of Uranium Resources of Yili Basin with the current China Categorization System

10. The current China Mineral Reserves and Resources Classification System (CMRRCS) for solid minerals was established in 1999[3,4]. It was formulated on the basis of the principles of the United Nations Framework Classification for Reserves/Resources – Solid Fuels and Mineral Commodities of 1997 (UNFC-1997). Both these systems use E, F, G axes (see Table 1). As shown in Table 1, CMRRCS has 16 categories.

Table 1.

China Mineral Reserves and Resources Classification System (CMRRCS) for solid minerals

<table>
<tr><td rowspan="3">Economic Viability</td><td colspan="4">Geological Study</td></tr>
<tr><td colspan="3">Identified mineral resources</td><td>Potential mineral resources</td></tr>
<tr><td>Measured</td><td>Indicated</td><td>Inferred</td><td>Prognostic</td></tr>
<tr><td rowspan="4">Economic</td><td>Mineable Reserve (111)</td><td colspan="2" rowspan="2"></td><td rowspan="6"></td></tr>
<tr><td>Basic Reserve (111b)</td></tr>
<tr><td>Pre-mineable Reserve (121)</td><td>Pre-minable Reserve (122)</td><td rowspan="5"></td></tr>
<tr><td>Basic Reserve (121b)</td><td>Basic Reserve (122b)</td></tr>
<tr><td rowspan="2">Marginal Economic</td><td>Basic Reserve (2M11)</td><td></td></tr>
<tr><td>Basic Reserve (2M21)</td><td>Basic Reserve (2M22)</td></tr>
<tr><td rowspan="2">Sub-Marginal Economic</td><td>Resource (2S11)</td><td></td></tr>
<tr><td>Resource (2S21)</td><td>Resource (2S22)</td></tr>
<tr><td>Intrinsically Economic</td><td>Resource (331)</td><td>Resource (332)</td><td>Resource (333)</td><td>Resource (334)</td></tr>
</table>

Note: (i) the first number represents economic viability, where 1 = economic, 2M = Marginal Economic, 2S = Sub-Marginal Economic, 3 = Intrinsically Economic. (ii) The second number represents status of project feasibility study, where1 = feasibility study, 2 = pre-feasibility study, 3 = Scoping study. (iii) The third number represents geological study, where 1= measured, 2 = indicated, 3 = inferred, 4 = prognostic. (iv) b = mineable reserve with no consideration of mining losses.

[3] Classification for resources/reserves of solid fuels and mineral commodities, China National Standard GB/T17766-1999, issued by the State Bureau of Quality and Technical Supervision (in Chinese).

[4] Specifications for uranium mineral exploration, China Geological and Mineral Resources Industry Standards DZ/T 0199-2002, issued by the Ministry of Land and Resources P.R. China (in Chinese).

11. The mapping of CMRRCS to UNFC-2009 is shown in Table 2.

Table 2.

Mapping of CMRRCS to UNFC-2009 Categories

No		CMRRCS			UNFC-2009		
		E	F	G	E	F	G
1	Economic Measured Minable Reserve	1	1	1	1	1	1
2	Economic Measured Basic Reserve	1	1	1b	1	1	1
3	Economic Measured Pre-minable Reserve	1	2	1	1	1 2, 1 3	1
4	Economic Measured Basic Reserve	1	2	1b	1	1 2, 1 3	1
5	Economic Indicated Pre-minable Reserve	1	2	2	1	1 2, 1 3	2
6	Economic Indicated Basic Reserve	1	2	2b	1	1 2, 1 3	2
7	Marginal Economic Measured Basic Reserve	2M	1	1	2	2 1	1
8	Marginal Economic Measured Basic Reserve	2M	2	1	2	2 1	1
9	Marginal Economic Indicated Basic Reserve	2M	2	2	2	2 1	2
10	Sub-Marginal Economic Measured Basic Reserve	2S	1	1	2	2 2	1
11	Sub-Marginal Economic Measured Basic Reserve	2S	2	1	2	2 2	1
12	Sub-Marginal Economic Indicated Basic Reserve	2S	2	2	2	2 2	2
13	Intrinsically Economic Measured Resource	3	3	1	2, 3 2, 3 3	2 1, 2 2, 2 3	1
14	Intrinsically Economic Indicated Resource	3	3	2	2, 3 2, 3 3	2 1, 2 2, 2 3	2
15	Intrinsically Economic Inferred Resource	3	3	3	2, 3 2, 3 3	2 1, 2 2, 2 3	3
16	Intrinsically Economic Prognostic Resource	3	3	4	3 2	3	4

12. Classification of the uranium resources of the Yili Basin was undertaken according to the mapping of CMRRCS to UNFC-2009 that is shown in Table 2 and results are shown in Table 3.

Table 3.

Classification of the Uranium Resources of the Yili Basin

Deposits	UNFC-2009 Class	UNFC-2009 Sub-Class	UNFC-2009 Categories	CMRRCS
Mengqiguer-2 (sandstone type)	Commercial Projects	On production	E1 1F1 1G2, E1 1F1 1G3	122b,332[a] 333
Mengqiguer-1 (coal type)	Non Commercial Projects	Development not viable	E3 3F2 3G2, E3 3F2 3G3	332 333
Kujiertai	Commercial Projects	On production	E1.1F1.1G1, E1 1F1 1G2, E1 1F1 1G3	121b, 122b,332[a] 333
Zhajistan	Commercial Projects	On production	E1 1F1 1G1 E1.1F1.1G2, E1.1F1.1G3	121b, 122b,33[a] 333
Wukuerqi	Commercial Projects	On production	E1 1F1 1G2, E1 1F1.1G3	122b,33[a] 333
Daladi	Non Commercial Projects	Development not viable	E3.3F2 3G2, E3.3F2 3G3	332 333
Honghaigou	Potentially Commercial Projects	Development Pending	E2F2.1G3	333

[a] Because definitive feasibility studies (DFS) or pre-feasibility studies (PFS) for the development of the deposit were done in the central area of the deposit and did not cover the extension area, the resources of the extension part of the deposit have not been converted into 122b from 332 in the existing CMRRCS report.

C. Application of UNFC 2009 to the uranium deposits of the Yili Basin

1. Mengqiguer Deposit

13. The Mengqiguer Deposit is the largest uranium deposit in the Yili Basin. The deposit accounts for about 45 per cent of the total uranium resources of the Basin. The uranium ore bodies are mostly hosted in the Xishanyao Formation and the Sangonghe Formation.

14. The uranium mineralization discovered during the 1950s and 1960s was found to be hosted in coal beds (named as Mengqiguer-1). The quantity is small. Since this material is difficult to process, this kind of coal type uranium mineralization is considered as "Development not viable" with categories E3.3 F2.3 G2, E3.3 F2.3 G3.

15. The uranium mineralization discovered after 2000 was found in permeable sandstone layers, which allows the uranium to be extracted with the ISL method (named as Mengqiguer-2). The ISL-amenable uranium resources of the deposit account for about 43 per cent of the total resources of the basin. Since the on-going trial uranium production with the ISL method in the deposit shows positive commercial results, this type of sandstone type uranium mineralization is considered as "On production" with categories E1.1 F1.1 G2, E1.1 F1.1 G3 (table 3). More geological work needs to be carried to increase the geological confidence of these resources.

2. Kujiertai Deposit

16. The Kujiertai Deposit is the second largest uranium deposit and the first ISL-mining uranium deposit in the Yili Basin, and also the first commercial ISL uranium production centre in China. The deposit accounts for about 23 per cent of total uranium resources of the basin. It was discovered in early1990s and the uranium ore bodies are mostly hosted in the permeable sandstone layers of the Xishanyao Formation and the Badaowan Formation. The uranium production of the deposit began in middle of 1990s using the ISL method. The uranium mineralization is considered as "On production" with categories E1.1 F1.1 G1, E1.1 F1.1 G2, E1.1 F1.1 G3.

3. Zhajistan Deposit

17. The uranium ore bodies of the Zhajistan Deposit are mostly hosted in the Xishanyao Formation and the Sangonghe Formation with the uranium resources constituting about 10 per cent of the total resources of the basin. The uranium mineralization is hosted in permeable sandstone layers and is being mined with the ISL method, in which case the uranium resources are considered as "On production" with categories E1.1F1.1G1, E1.1F1.1G2, E1.1F1.1G3.

4. Wukuerqi Deposit

18. The uranium ore bodies of the Wukuerqi Deposit are mostly hosted in the Xishanyao Formation and the Sangonghe Formation with the uranium resources constituting about 7 per cent of the total uranium resources of the basin. The uranium mineralization is hosted in permeable sandstone layers and is being mined with the ISL method, so the uranium resources are considered as "On production" with categories E1.1 F1.1 G2, E1.1 F1.1 G3. However, more geological work needs to be carried out to increase its geologic assurance.

5. Daladi Deposit

19. The Daladi Deposit is the earliest discovered uranium deposit in the Yili Basin. The uranium ore bodies are mostly hosted in the Xishanyao Formation and the Sangonghe Formation with the uranium resources being less than 3 per cent of the total resources of the

Basin. The uranium mineralization is hosted in the coal beds and is difficult to process, so these uranium resources are considered as "Development not viable" with categories E3.3F2.3G2, E3.3F2.3G3.

6. Honghaigou Deposit

20. The Honghaigou Deposit is a new Deposit that was discovered in recent years, and the exploration and the pre-feasibility studies are still ongoing in the Deposit. The uranium ore bodies are mostly hosted in the Upper Jurassic and the Xishanyao Formation with the uranium resources constituting about 12 per cent of the total resources of the basin. The uranium mineralization is classified into "333" in the current CMRRCS. However, considering that the uranium mineralization is hosted in permeable sandstone with similar mineralization characteristics to that of the Kujiertai Deposit, and that the deposit can be mined using the ISL method, the uranium resources are considered as "Development Pending" with categories E2 F2.1 G3.

D. Conclusions

21. From this case study on the application of UNFC-2009 to the uranium resources in the Yili Basin, it can be concluded that if a comprehensive consideration of the project socio-economic viability and project status and feasibility is undertaken, the mapping of CMRRCS Classes to UNFC-2009 Classes will be relatively easy and straight forward. UNFC-2009, in particular with its Sub-classes, is a very useful uranium resources categorization tool because it can provide an overall picture of a uranium project. Additionally, UNFC-2009 can express the project more comprehensively and more precisely than UNFC-1997 and CMRRCS, especially in relation to project status and feasibility.

III. Case Study – Application of UNFC-2009 to the uranium resources of the Azelik Deposit, Niger

22. This case study was prepared with the input of Mr. Li Shengxiang of the China National Nuclear Corporation (CNNC), Mr. Harikrishnan Tulsidas of IAEA and Mr. Brad Van Gosen of USGS.

23. The Azelik Uranium Deposit is located in the north-western region of Niger. It is a sandstone-type uranium deposit hosted in the Cretaceous strata of the Tim Mersoï Basin. Based on the geological survey, core observation and documentation, the uranium mineralization is related to hydrothermal fluid flow[5].

24. In 2006, the China National Nuclear Corporation acquired the project and conducted an estimation of the uranium resources through application of the China Mineral Reserves and Resources Classification System (CMRRCS). The resource estimation was carried out prior to the Definitive Feasibility Study (DFS) being undertaken. In 2008, China National Nuclear Corporation completed the DFS for the project, following which construction of the mine began.

[5] Nie Fengjun et al. 2009. Progress report on nuclear science and technology in China (Vol.1). Proceedings of Academic Annual Meeting of China Nuclear Society, No.6.

25. The aggregate uranium resources estimation according to CMRRCS before carrying out the DSF was 13,692.3 metric tons of uranium (tU). After completing the DFS, the aggregate resources according to CMRRCS were estimated to be 12,763.1 tU (Table 4).

Table 4.

Estimated uranium resources of the Azelik Deposit, calculated before and after the Definitive Feasibility Study (DFS)

Deposit	*Type*	*Resources before DFS*			*Resources after DFS*			
		CMRRCS Category	CRIRSCO[a] Template	tU	CMRRCS Category	CRIRSCO Template	NEA/IAEA "Red Book" Classification	tU
Azelik	Sandstone	331	Measured Resources	18,20 80	111	Proven Reserves	RAR (<USD 130/KgU)	1,820 8
		332	Indicated Resources	8,788 3	122[b]	Probable Reserves	RAR (<USD 130/KgU)	8,664 4
		333	Inferred Resources	3,083 2	2M22[b]	Inferred Resources	IR (<USD 130/KgU)	2,277 9
Total				13,692 3				12,763.1

[a] Committee for Mineral Reserves International Reporting Standards (CRIRSCO).

[b] In view that the geological confidence was not high enough due to insufficient infill drilling during the DFS, China National Nuclear Corporation transferred the former 332 into 122 and 333 into 2M22 by excluding some high-cost resources. The feasibility study level was lowered to pre-feasibility study results rather than moving the resources into proven reserves.

A. The Case Study

26. The Estimated uranium resources of the Azelik Deposit after the DFS were classified according to the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009). The mapping to the Organisation of Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA)/International Atomic Energy Agency (IAEA) resource reporting scheme (also known as the "Red Book") and CMRRCS is shown in Table 5. This is aided by the mapping scheme described for CMRRCS and UNFC-2009.

Table 2.

Estimated uranium quantities in the Azelik Project classified under UNFC-2009 (as at December 2010)

Project	UNFC-2009				NEA/IAEA "Red Book" Classification			CMRRCS	
	Class	Sub-class	Categories	(tU)	Production Centre Status	Classification	(tU)	Class	(tU)
Azelik	Commercial Project	On Production	E1 1F1.1G1	1,820.8	Existing	RAR[a] <$130/Kg	10,485.2	111	1,820.8
			E1 1F1.1G2	8,664 4				122	8,664.4
Azelik	Potentially Commercial Project	Development Pending	E2F2.1G3	2,277 9	Prospective	IR[b] <$130/Kg	2,277.9	2M22	2,277.9
Total				**12,763.1**			**12,763.1**		**12,763.1**

[a] Reasonably Assured Resources.

[b] Inferred Resources.

B. Conclusions

27. In this Case Study, the cost categories as used in the NEA/IAEA "Red Book" classification are also used for each of the Classes. This example shows that mapping of the existing CMRRCS categories and quantities to the NEA/IAEA "Red Book" Classification and UNFC-2009 can be carried out in a straightforward manner.

28. Even though the mapping of UNFC-2009 to CMRRCS has been defined only at a Class level, the use of Sub-classes – as in this case study – can add further information about the project and application of the UNFC-2009 principles and generic specifications. Thus, the full granularity of UNFC-2009 can be applied to derive maximum benefits.

IV. Observations, Conclusions and Recommendations

29. The work undertaken in preparing the two case studies usefully demonstrates that quantities can be transparently transferred to UNFC-2009 from CMRRCS.

30. The Yili Basin case study highlighted issues related to the use of UNFC-2009 for In-situ Leaching (ISL). It was noted that there are examples in Australia, Kazakhstan and USA where the CRIRSCO Template is applied to ISL projects. In some cases this can generate debate due to the fact that the recovery factor is usually a major uncertainty. Application of UNFC-2009 can facilitate representation of this uncertainty through use of the G-axis categories.

31. The Azelik Uranium Deposit case study demonstrates that mapping of the existing CMRRCS categories and quantities to the NEA/IAEA "Red Book" Classification and UNFC-2009 can be carried out in a straightforward manner.

32. Even though the mapping of UNFC-2009 to CMRRCS has been defined only at a Class level, the use of Sub-classes – as in the Azelik Uranium Deposit case study – can add further information about the project and application of the UNFC-2009 principles and generic specifications. Hence, the full granularity of UNFC-2009 can be applied to derive maximum benefits.

33. The two case studies serve to confirm that there would appear to be a straightforward relationship between the CMRRCS Classes and the UNFC-2009 Classes and hence consideration may now be given to the possible development of a Bridging Document between the two systems.